Airport Capacity Enhancement

Tactical Initiative

Charlotte/Douglas International Airport

Taxiway System Improvements

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September 1995

Prepared jointly by the U.S. Department of Transportation, Federal Aviation Administration, the City of Charlotte Aviation Department, and the airlines and general aviation community serving Charlotte/Douglas International Airport.

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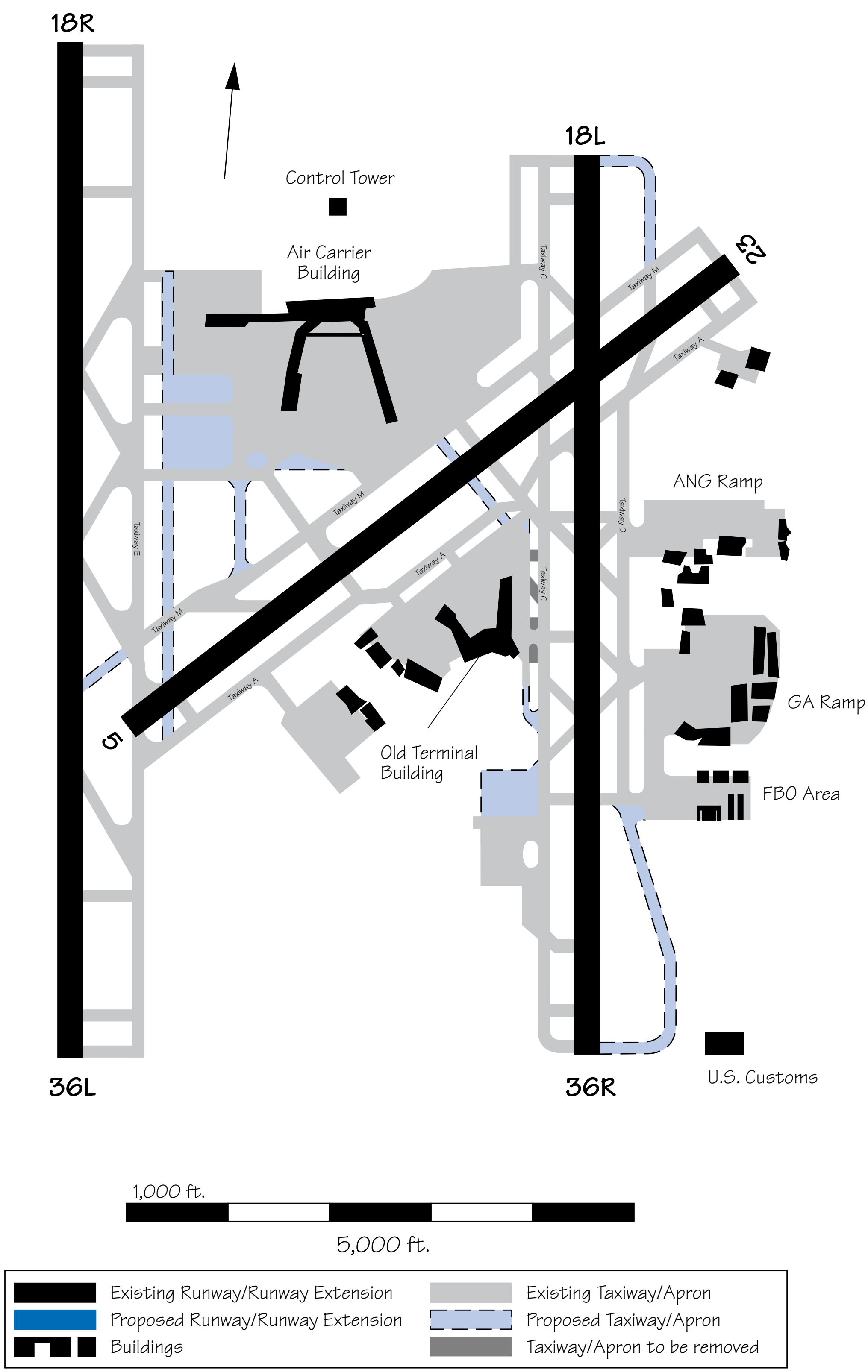

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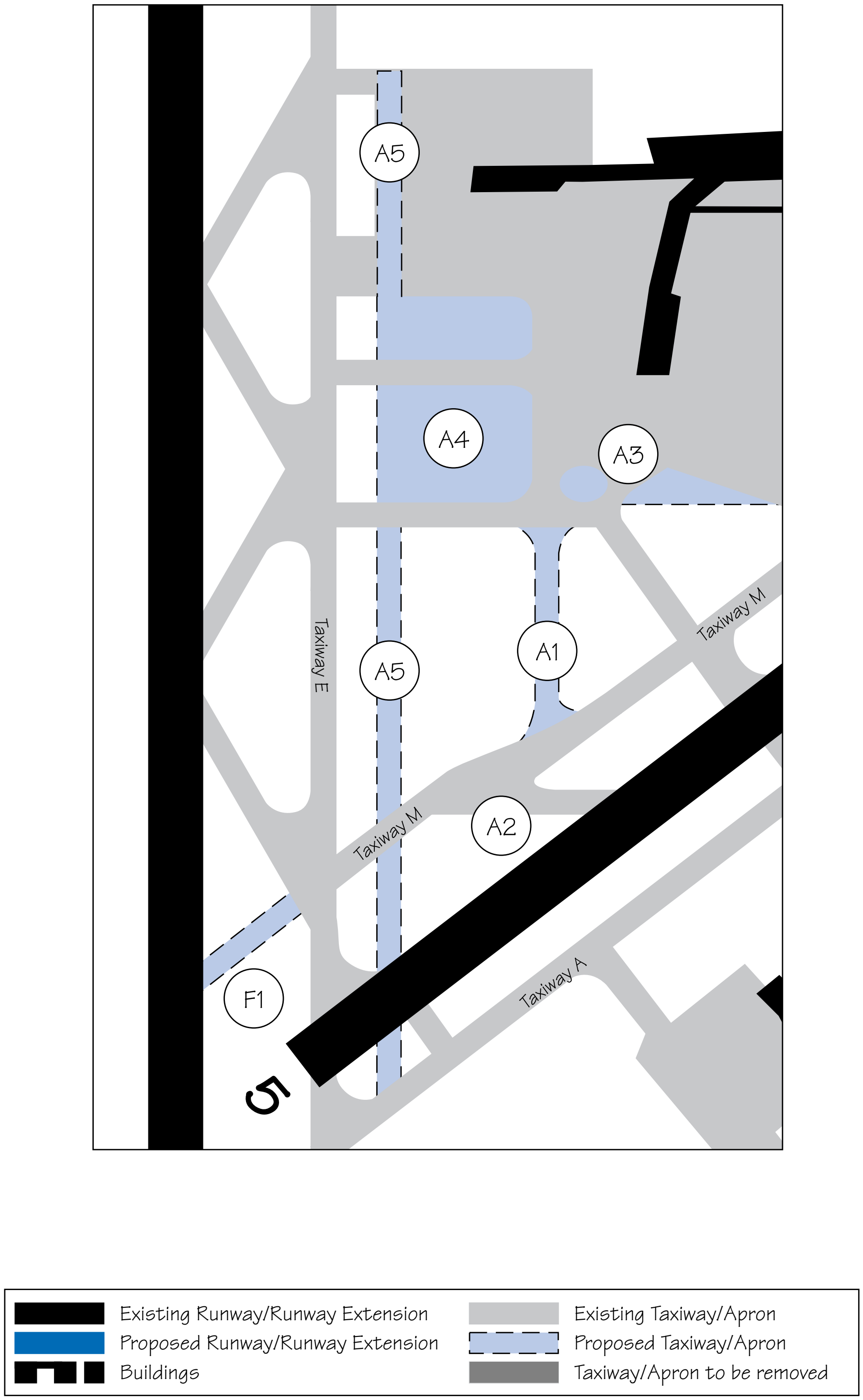

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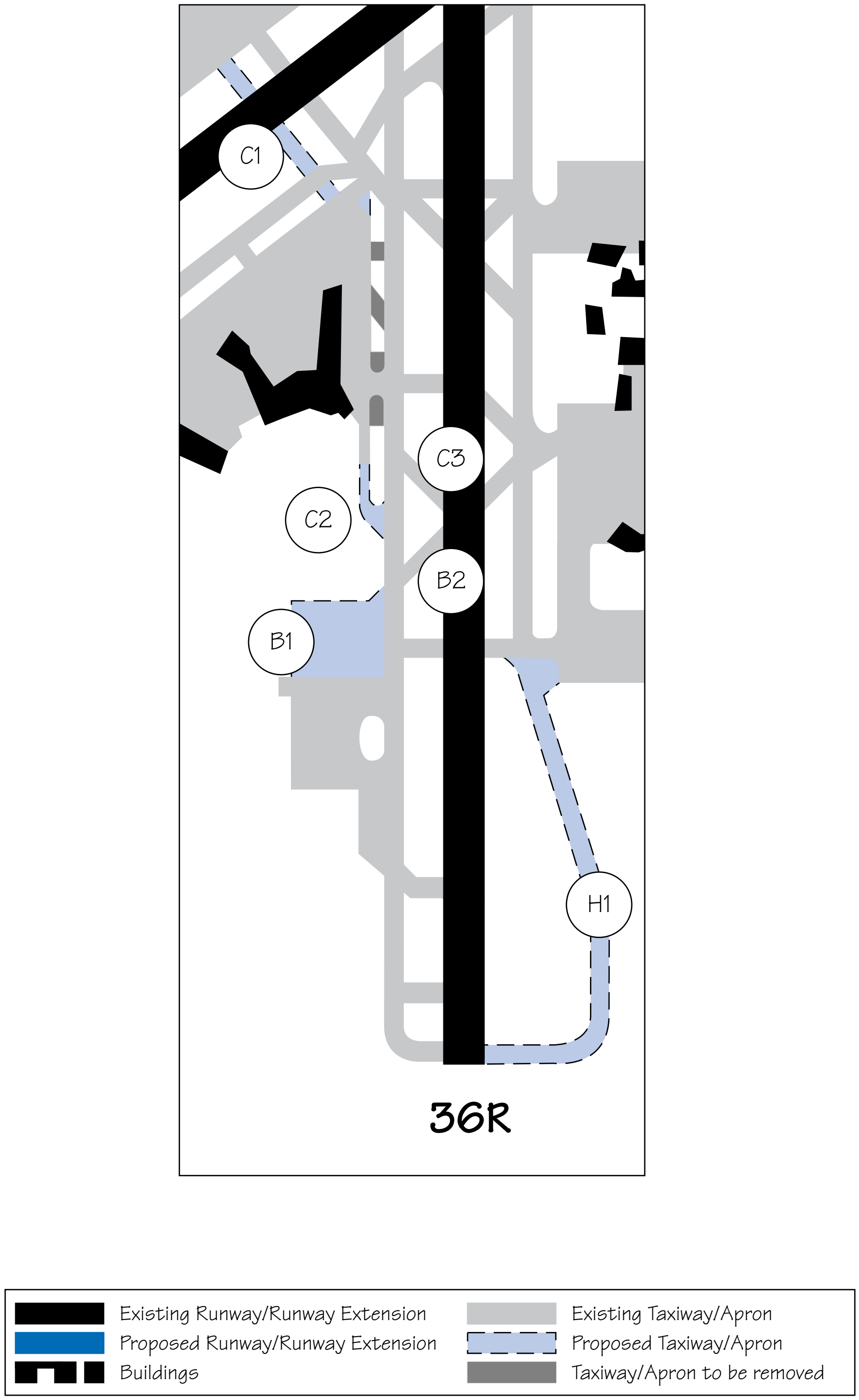

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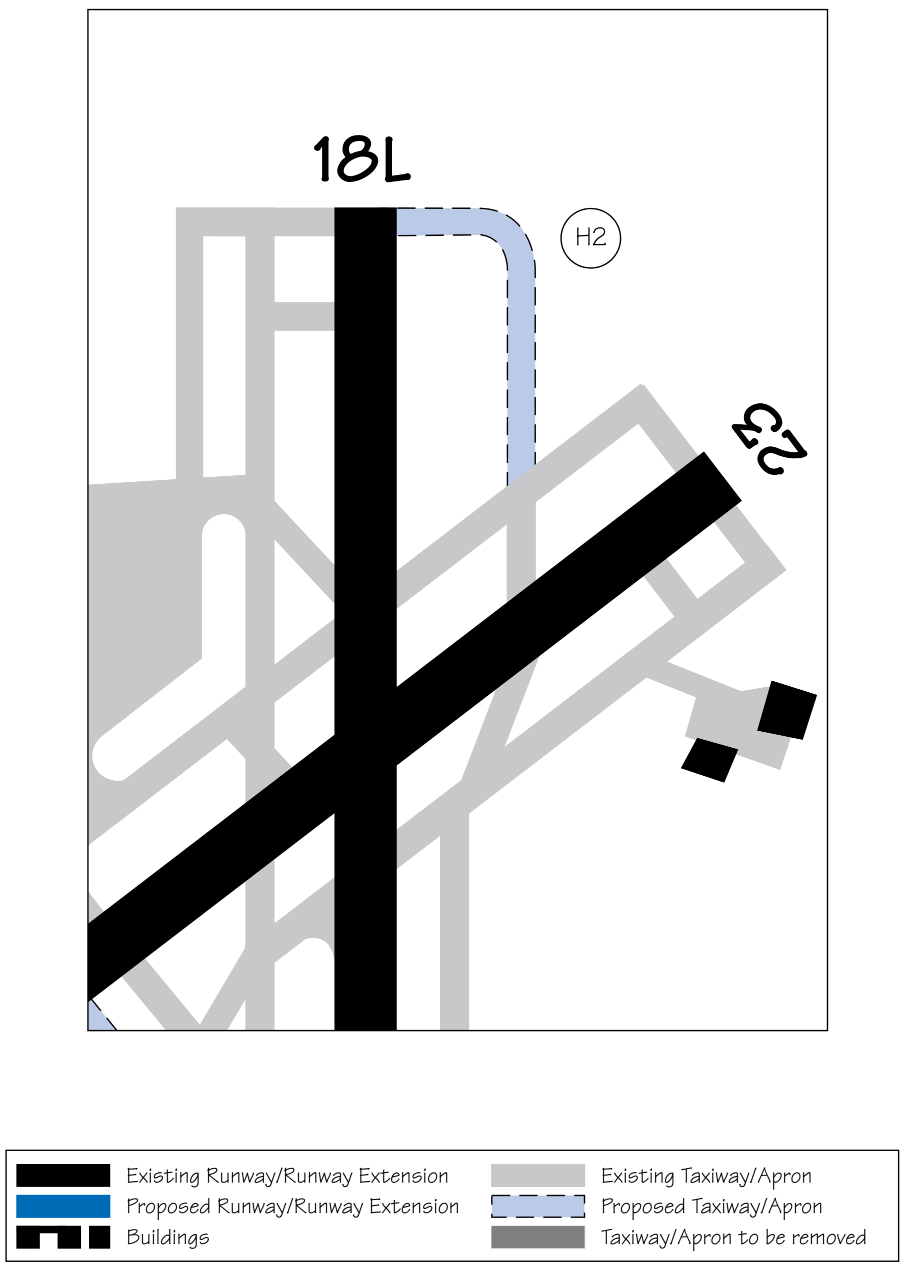

Figure 5. Taxiway System Improvements and Annual Delay Savings

	Estimated Annual Delay Savings[1] (in hours and millions of 1994 dollars) Future 1 (520,000)	Future 2 (600,000)
1. Projects A3, A4, and A5	2,845/$4.6	23,784/$38.8
2. Projects A1, A3, A4, and A5	5,023/$8.2	28,661/$46.7
3. Projects A3, A4, A5, and C1	4,102/$6.7	40,050/$65.3
4. Projects A3, A4, A5, C1, and C2	4,308/$7.0	39,972/$65.2
5. Projects A3, A4, A5, C1, C2, and H1	4,351/$7.1	40,018/$65.2
6. Projects A3, A4, A5, C1, C2, and H2	4,613/$7.5	40,815/$66.5

1. The delay savings benefits of these improvements are not necessarily additive.

Note: The delay savings of each improvement package above represents its delay cost less the delay cost of the Do Nothing (Existing Airport) case. Improvements 3 through 6 do not include project A1, therefore, they should be compared only to improvement 1 to determine their additional benefit over projects A3, A4, and A5.

Section 1

Introduction

Objective

The City of Charlotte Aviation Department and the Federal Aviation Administration (FAA) initiated this study to evaluate capacity and efficiency initiatives which could result in delay saving benefits (improved taxi times). The objective of this initiative was to analytically evaluate the impact of various combinations of airport ground infrastructure improvements and their effects upon delay. In addition, further benefits have accrued in dynamically exploring, through the use of simulation, airport design alternatives which provide for improved operational performance affecting both the safe and efficient use of the airport ground infrastructure of gates, aprons, taxiways, runway exits, and runways.

Background

Since 1985, the FAA has sponsored Airport Capacity Design Team Studies at airports across the country affected by delay. Representatives from airport operators, air carriers, other airport users, and aviation industry groups have worked together with FAA representatives to identify and analyze capacity problems at each individual airport and recommend improvements which have the potential for reducing delays. The improvements recommended by the Capacity Design Teams have emphasized construction of new runways and taxiways, installation of enhanced navigation facilities and equipment, and changes in air traffic control procedures. Typically, these improvements are implemented through established, long-term planning processes.

The FAA's Office of System Capacity and Requirements (ASC) has recently undertaken a series of initiatives to identify, evaluate, and implement capacity improvements which are achievable in the near term and will provide more immediate relief for chronic delay-problem airports. Airport Capacity Enhancement (ACE) Action Teams will be established at selected airports, again made up of representatives from airport operators, air carriers, other airport users, FAA, and aviation industry groups , to assess these near term, tactical initiatives and guide them through implementation.

An Airport Capacity Design Team Study at Charlotte/Douglas International Airport (CLT) was completed in April 1991 with the publication of the *Charlotte/Douglas International Airport Capacity Enhancement Plan*. The Plan recommended, for immediate action, the construction of several airfield improvements, including a third parallel runway (18W/36W), the extension of Runway 36R to the south, the extension of Taxiway D to the ends of Runway 18L/36R, angled exits off Runways 18L and 23, and departure sequencing pads at all runway ends. The City of Charlotte completed the extension of Runway 36R in early 1994. They completed the construction of angled exits off Runways 18L and 23 in 1995. CLT recently started the process for environmental approval of the new Runway 18W/36W.

Activity at CLT has continued to increase since the 1991 study. In 1991, the airport handled 441,000 aircraft operations (landings and takeoffs), and in 1994, 470,000 aircraft operations. In response to this steady growth in traffic, the City of Charlotte Aviation Department is preparing a plan to enhance the capacity of the airport's taxiway system to accommodate the increase in activity. The City requested that the FAA assist them in evaluating the benefits of the proposed taxiway improvements and in determining the optimum time to implement them. In response, the FAA formed the CLT Airport Capacity Enhancement (ACE) Action Team in October 1994 to conduct this study.

Scope

The ACE Action Team limited its analysis to aircraft activity within the terminal area airspace and on the airfield. They considered the technical and operational feasibility of the proposed airfield improvements, but did not address environmental and design issues or the cost of development and construction. These issues need to be addressed in future airport planning studies. The data generated in this study may be used in these follow-on studies.

For the purposes of this study, the ACE Action Team evaluated the taxiway improvements at two future activity levels, Future 1 and Future 2, as established in the April 1991 Plan, at 520,000 and 600,000 annual aircraft operations respectively. These were the same future activity levels used in the 1991 capacity study and were adopted by ACE Action Team consensus.

Methodology

The ACE Action Team, consisting of the FAA, the City of Charlotte Aviation Department, and various industry representatives (see Appendix A), met periodically for review and coordination. The Team considered various airfield configuration options. In order to evaluate the options, the Team determined the delay savings (improved taxi times) which would result from the individual improvements or various combinations of improvements.

The basis for this report was the *Charlotte/Douglas International Airport Capacity Enhancement Plan* completed in 1991. It provided the necessary data base for the calculations of taxi and delay times and served as a baseline for the determination of benefits and cost efficiencies.

Several key factors from the 1991 study were included in this study, including the method of calculating annual delay. In addition, airport configuration data analyzed in the previous study, including traffic flow and the distribution of aircraft on the runways, were used. Appendix B of this report depicts some of the data from the 1991 report which was used in this effort.

The FAA's Technical Center used the Airfield Delay Simulation Model (ADSIM) to analyze the various airfield configuration options and determine daily total aircraft travel times and ground delays. Differences in the daily total travel times between the options represented the daily delay savings (improved taxi time) of one option compared to another. These daily delay savings were annualized and multiplied by the average direct operating cost of the aircraft fleet operating at CLT ($1,630 per hour in 1994 dollars) to determine the annual delay savings of each improvement in terms of dollars.

Section 2

Taxiway System Improvements

Taxiway Development Plan

The City of Charlotte Aviation Department is developing a Taxiway Development Plan to guide their implementation of improvements to CLT's taxiway system. The information obtained in this tactical capacity study will help them finalize this plan. The Preliminary Taxiway Development Plan was used as the basis for grouping taxiway construction projects into packages for ADSIM modeling.

The City of Charlotte Aviation Department (CCAD) made several assumptions in the formulation of the Taxiway Development Plan. These are described in the following discussion points:

- The separation between centerlines of adjacent taxiways and runways should be 600 feet to allow fully developed high speed runway exits compliant with FAA airport design standards and to accommodate Group VI, Category D aircraft. As an alternative, 400 feet is an acceptable centerline separation when high speed runway exits and Group VI aircraft are not a design consideration.
- A minimum separation of 324 feet is required between the centerlines of adjacent parallel taxiways or taxiways and taxi lanes to accommodate Group VI aircraft. This distance can be reduced to 267 feet to accommodate Group V aircraft, but it should be noted that this may create operational limitations for Group VI aircraft.
- The removal of some current taxiways was considered to reduce taxiway complexity and complement new taxiway plans. Because the recommended new taxi routes are designed for dedicated use, the adoption of a color-coded taxi route system should be evaluated as a method to reduce both pilot-controller workload and error.
- The timing for the relocation of Taxiway A (i.e., Group G below) may need to be reconsidered in view of concerns associated with the operation of the Concord Airport. The location of the Concord Airport places it directly below the flight path of arrivals to Charlotte Runway 23. Because of the lack of vertical precision approach guidance to Runway 23, there is FAA air traffic concern that aircraft on final to Runway 23 may descend to altitudes potentially in conflict with aircraft operating in, to, or from the Concord traffic pattern. If this concern is validated, it strongly justifies placement of an ILS on Runway 23.

Following is CCAD's current grouping and descriptions of taxiway improvements and related projects (See Figures 2, 3 and 4 for graphic depiction of these projects).

Group A: Aircraft Arriving Runway 23 and Departing Runways 5 and 36L (Partial Dual Parallel Taxiway, Ramp, and High Speed Runway Exit)

Group A projects provide a partial dual parallel taxiway system that will allow aircraft to bypass one another and permit opposite direction traffic flows for the aircraft arriving on Runway 23 and departing Runways 5 and 36L. The additional ingress and egress routes into the expanded terminal apron will not only facilitate the dual taxi flow, but also facilitate holding and gate staging, decrease push back and passing interactions, and reduce congestion in the west terminal area.Project A1 provides ramp access from Runway 23.

Project A2 .... is the construction of a high speed runway exit from Runway 23. This project is complete.

Projects A3 and A4 .... provide additional ramp area which facilitates transit to and from Runways 23, 5, 36L and 18R and can serve as a "hard stand" (holding) area if necessary. They should cure the Concourse A and B ramp area passing problem by providing more passing area around the concourses.

Project A5 .... is a partial dual parallel taxiway to Runway 18R/36L and provides a bypass taxiway for aircraft departures from Runway 36L or arrivals from Runways 18R and 23.

Group B: Aircraft Arriving 18L (Ramp and High speed Runway Exit)

Group B projects support the implementation of the taxiway system planned under Group C. They permit turbojet arrivals on Runway 18L to expedite exiting the runway via a high speed exit and either taxi north on Taxiway C or exit directly to a ramp area. Group B Projects will reduce average runway occupancy times for turbojet aircraft.

Project B1 .... completed a ramp area to permit aircraft using the planned Runway 18L high speed exit to proceed directly, and without delay, to a ramp area.

Project B2 .... provided turbojet aircraft arriving Runway 18L an optimized high speed runway exit which reduces average runway occupancy times. This project is complete.

Group C: Aircraft Arriving and Departing Runway 36R (Taxiways and High speed Runway Exit)

Three taxiway projects have been identified to support aircraft arriving and departing on Runway 36R. These projects, when complete, will reduce runway occupancy time by allowing commuter aircraft to exit from the active runway at an optimally located high speed runway exit. Further, the establishment of independent taxi flows to and from the active runway will enhance operational efficiency, reduce delay, and contribute to safety by simplifying taxi routes to and from runway and ramp and eliminating ground path conflicts.

Note that the optimal high speed runway exit distance from the runway threshold for turbojet aircraft used at CLT is 5,500 feet. Runways 18R , 18L, 36L, and 23 all have current or planned exits at this distance. The exception is Runway 36R which has a high speed exit located 4,900 feet from the threshold.

Project C1 .... will permit aircraft arriving on Runway 36R and aircraft departing Runway 36R to simultaneously taxi across Runway 5/23.

Project C2 .... permits non-interfering taxi routes to and from the terminal ramp for aircraft arriving and departing Runway 36R. The successful development of this improvement is contingent upon adequate taxi lane/taxiway clearance from cargo buildings and ramps.

Project C3 .... provides commuter aircraft arriving Runway 36R an early high speed runway exit, reducing average runway occupancy times. This project is complete.

Group D: Aircraft Arriving Runway 36R (Simultaneous Operations to Intersecting Runways - Hold Short Lights and Signs)

Project D1 .... provides the necessary hold short signage and lighting, including in-runway lighting and remote light control, which will be required by FAA to conduct simultaneous arrivals to Runways 36R and 5. (Not depicted on Figure 3.)

Group E: All Runways and Taxiways (Surface Movement Guidance and Control Taxiway and Runway Lighting)

Project E1 .... addresses requirements for in-taxiway lighting required to support airport operations for low visibility conditions (i.e., below 1,200 feet RVR and 600 foot RVR) in support of ASDE capability. (Not depicted on Figures 2, 3, or 4.)

Group F: Commuter Aircraft Departing Runway 36L (New Taxiway for Intersection Departure)

Project F1.......... addresses the potential requirement for a high use of intersection departures from Runway 36L for commuter aircraft.

Group G: Aircraft Arriving Runway 23 (Relocation of Taxiway)

Project G1......... supports the relocation of Taxiway A to permit the installation of an ILS Glideslope for Runway 23. (Not depicted on Figures 2, 3, or 4.)

Group H: General Aviation and Military Aircraft Departing Runway 18L and 36R (Taxiway Extension)

Historically, the preferred departure taxi route for general aviation aircraft from the Fixed Base Operator (FBO) and for North Carolina Air National Guard (ANG) C130s was Taxiway "A" intersection for Runway 18L, and Taxiway "D2" intersection for Runway 36R. However, many high performance general aviation aircraft are requesting full length departures. There is considerable growth in corporate type general aviation traffic of which increasing numbers will need the full length of the runway for departures. These taxiway projects will reduce the number of aircraft that must cross Runway 18L/36R.

Air National Guard C130s have made formation departures, which require the full length of the runway, a high training priority. Since Taxiway "D" does not extend to the full length of Runway 18L/36R, both of these type users must cross the runway to access Taxiway "C". These midfield runway crossing situations present the potential for taxiway congestion and increase the possibility of a runway incursion, especially for the C130s who have a need to taxi in formation.

Landing formation flights also presents problems. The aircraft must roll to the end of the runway to turn off, thereby increasing runway occupancy time. The aircraft block high-speed exits for other landing aircraft as they taxi in, and again must cross Runway 18L/36R to ingress into the ANG Ramp.

For those aircraft who elect to depart from the intersections, wake turbulence rules must be considered, increasing complexity for controllers and safety issues and delays for pilots. Multiple runway crossings also contribute to delays for those aircraft in the terminal ramp waiting in the departure queue.

The potential for degradation of safety and efficiency is greatly multiplied at night and during instrument weather conditions. Nighttime runway crossings, with ambient lighting and the associated blending of different colored airport and aircraft lights is a serious consideration. The general restricted visibility during Instrument Meteorological Conditions (IMC) also magnifies these problems.

While the benefits of these taxiway projects are not as easily defined as some others in terms of dollar savings, they are justified on their merits of enhanced safety and efficiency of aircraft operations.

Project H1......... is the extension of Taxiway D to the south to provide the General Aviation and Air National Guard users on the east side of Runway 18L/36R direct access to the Runway 36R departure end.

Project H2......... is the extension of Taxiway D to the north to provide General Aviation and Air National Guard users on the east side of Runway 18L/36R direct access to the Runway 18L departure end.

Taxiway System Improvements Evaluated

Figure 1 shows the current layout of the airport. Figures 2, 3, and 4 depict the location of each of the taxiway improvement projects (excluding Projects D1, E1 and G1).

Figure 5 lists the taxiway system improvements evaluated by the ACE Action Team and presents the estimated annual delay savings for each improvement in millions of dollars.

The dollar value of $27.17 per minute or $1,630.00 per hour was used to compute delay savings at both demand levels. These values reflect the average direct aircraft operating cost for the CLT fleet mix in 1994 dollars.

Figure 6 lists each taxiway system improvement evaluated by the ACE Action Team and presents the estimated construction cost of each project in millions of dollars.

The following assumptions were made for the ADSIM analysis:

- Use of Runway 5/23;
- Use of land-and-hold-short procedures for Runway 36R;
- Existing Airport (Do Nothing) case and each improvement evaluated assumed angled exits on Runway 23 (Project A2), Runway 18L (Project B2), and Runway 36R (Project C3) were in place and operational. Construction of these exits is complete.

Figure 6. Taxiway System Improvements Evaluated and Estimated Construction Costs

Improvement	Estimated Cost
1. Projects A3, A4, and A5 in conjunction	$14.4 Million
2. Projects A1, A3, A4, and A5 in conjunction	$18.1 Million*
3. Projects A3, A4, A5, and C1 in conjunction	$15.9 Million*
4. Projects A3, A4, A5, C1, and C2 in conjunction	$16.7 Million**
5. Projects A3, A4, A5, C1, C2, and H1 in conjunction	$21.0 Million***
6 Projects A3, A4, A5, C1, C2, and H2 in conjunction	$19.2 Million***

Note: Projects A2, B2, and C3 are included in the Do Nothing (existing airport) scenario due to the fact that construction has been completed on these projects.

* Includes $14.4 Million for projects A3, A4, and A5.

** Inclused $15.9 million for projecxts A3, A4, A5, and C1.

*** Includes $16.7 million for projects A3, A4, A5, C1, and C2.

Taxiway System Improvements Not Evaluated

Although a series of ground infrastructure improvements have been enumerated (i.e., Group A through Group H), a few of these initiatives do not have quantifiable benefits consistent with the application of the methodology chosen for benefit analysis. For example, Project B1 represented an expanded apron for alternative ramp access in an area without aircraft movement constraints. Therefore, dynamic simulation would not show operational dependencies and would not generate delay scenarios. This was also true of Projects D1 and E1, which were established to comply with future regulatory requirements for signage and lighting in conducting land-and-hold-short operations to intersecting runways and in conducting operations in low visibility conditions.

Project F1 would support a high use of intersection departures for commuter aircraft on Runway 36L. These intersection departures can only be conducted during daytime visual meteorological conditions, not during instrument meteorological conditions. The CLT ATCT's current estimate of the number of intersection departures on Runway 36L using Exit E5 is 15 DH-8 aircraft per day. Since intersection departures are currently being conducted from Exit E5, ADSIM simulations of those same departures using proposed Project F1 instead would show no benefit over the Do Nothing case. Therefore, Project F1 was not evaluated.

Project G1 was not evaluated because the difference in taxi times before and after the taxiway relocation would be insignificant.

Section 3

Results and Recommendations

Figure 5 lists the estimated delay savings benefits of each improvement evaluated by the ACE Action Team.

At Future 1, each successive improvement shows an increase in delay savings over the previous improvement, particularly improvements 1 and 2 which show an increase in savings of $4.6 million and $3.6 million respectively. This brings the total savings in Future 1 to $8.2 million.

At Future 2, each successive improvement shows an increase in delay savings over the previous improvement, except for improvements 4 and 5 which show a decrease in savings of $0.1 million and no change in savings respectively. However, these improvements may have additional safety and efficiency benefits that cannot be quantified by the methods used in this study as discussed in Section 2. For example, improvements 5 and 6 have significant aircraft operational safety and efficiency benefits.

The results of this Airport Capacity Tactical Initiative clearly demonstrate the significant benefits achievable in terms of reduced ground delays through the implementation of the airport ground infrastructure improvements contained in the City of Charlotte's Taxiway Development Plan. Therefore, the ACE Action Team strongly recommends that the City of Charlotte take any and all necessary actions to implement the improvements which have been clearly validated by their delay savings benefits. This report should serve as an independent objective basis for this determination and for subsequent airport actions.

In addition, the ACE Action Team recommends that the City of Charlotte pursue implementation of those improvements that offer significant aircraft operational safety and efficiency benefits that could not be quantified in this study.

Appendix A

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Appendix B

Data Inputs and Assumptions

For this report, the following assumptions were made for the Do Nothing or Baseline simulation runs:

- Demand levels of 530,000 and 600,000 annual airport operations, using the demand profiles established in the 1991 Charlotte/Douglas International Airport Capacity Enhancement Plan.
- Use of Runway 5/23.
- Use of land-and-hold-short procedures for Runway 36R.
- Include angled exits from Runway 23 (Project A2), Runway 18L (Project B2), and Runway 36R (Project C3).

Following are some of the data inputs and assumptions from the 1991 capacity study that were used in this study.

Figure 7 shows current airfield weather conditions. Figure 8 shows the daily traffic demand distribution by aircraft class. Figure 9 lists the aircraft approach speeds. Figure 10 lists departure runway occupancy time.

Figure 11 illustrates the average-day, peak-month demand levels for CLT for each of the annual activity levels used in the study, Future 1 and Future 2. This data was taken from the 1991 study where the hourly traffic counts were derived from the tower counts for January 31, 1990. The air carrier data were based on the January 31, 1990, Official Airline Guide. For Future 1, the total number of hourly operations peak at 132 with 60 arrivals and 72 departures. Peak hour total demand level for Future 2 is 148 operations consisting of 67 arrivals and 81 departures.

Figure 7. Airfield Weather (Ref: 1991 CLT Report)

Weather	VFR	IFR 1	IFR 2
Minima	Visual	CAT I	CAT II
Ceiling (AGL)	2,100′	200′	150′
Visibility	3 sm	2,400′	1,600′
North Flow	45.0%	3.5%	1.5%
South Flow	45.5%	3.1%	1.4%
Total	90.5%	6.6%	2.9%

VFR: Visual Flight Rules
IFR: Instrument Flight Rules
sm: statute miles

Figure 8. Daily Traffic Demand Distribution by Aircraft Class (Ref 1991 CLT Report)

Aircraft Class	Aircraf Types	Baseline (430,000)	Future 1 (520,000)	Future 2 (600,000)
Class 4	Single-engine props 12,500 lbs. or less	3%	3%	2%
Class 3	Twin-engine props 12,500 lbs. or less	5%	5%	5%
Class 2	Large aircraft 12,500 to 300,000 lbs. & small jets	90%	88%	86%
Class 1	Heavy aircraft over 300,000 lbs.	2%	5%	7%

Figure 9. Approach Speeds (Ref 1991 CLT Report)

Weather	Class 1	Class 2	Class 3	Class 4
VFR	140 kts	130 kts	115 kts	90 kts
IFR	170 kts	170 kts	125 kts	90 kts

Figure 10. Departure Runway Occupancy Times (Ref 1991 CLT Report)

Class	Class 1	Class 2	Class 3	Class 4
Seconds	39	39	34	34

Figure 11. Annual and Daily Demand Levels (Ref 1991 CLT Report)

	Annual Operations	Daily Operations	Equivalent Days
Future 1	520,000	1,635	318
Future 2	600,000	1,887	318

Appendix C

Computer Model and Methodology

The Charlotte/Douglas International Airport ACE Action Team evaluated the delay savings benefits (improved taxi times) of various taxiway system improvements. The analysis was performed using computer modeling techniques. A brief description of the model used and the methodology employed follows.

Airfield Delay Simulation Model (ADSIM)

The Airfield Delay Simulation Model is a fast-time, discrete event model that employs stochastic processes and Monte Carlo sampling techniques. It describes significant movements of aircraft on the airport and the effects of delay in the adjacent airspace. The model was validated in 1978 at Chicago O'Hare International Airport against actual flow rates and delay data. It was calibrated for this study against field data collected at CLT to insure that the model was site specific.

Inputs for the simulation model were derived from empirical field data. The model repeated each experiment 10 times using Monte Carlo sampling techniques to introduce system variability, which occurs on a daily basis in actual airport operations. The results were averaged to produce output statistics. Total and hourly aircraft delays, travel times, and flow rates for the airport and for the individual runways were calculated.

Methodology

The experiments were conducted by calculating the average taxi times for arrivals from each runway to each gate area and for departures from each gate area to each runway for both the north and south traffic flow.

The distribution of departures from each gate area to each runway was used to calculate the total taxi time for departures. Likewise, the distribution of arrivals from each runway to each gate area was used to calculate the total taxi time for arrivals. The calculations were repeated for each taxiway configuration listed in Section 2 at each demand level (520,000 and 600,000 annual aircraft operations).

For the delay analysis, FAA specialists developed traffic distributions based on the *Official Airline Guide*, historical data, and various forecasts. Aircraft volume, mix and peaking characteristics were developed for two demand periods, Future 1 and Future 2. The estimated annual delays for the proposed improvement options were calculated from the experimental results. These estimates took into account the yearly variations in runway configurations, weather, and demand based on historical data.

The potential delay reductions for each improvement were assessed by comparing the annual delay estimates with the Do Nothing case.

APPENDIX D

LIST OF ABBREVIATIONS

ACE	Airport Capacity Enhancement
ADSIM	Airfield Delay Simulation — computer simulation model
ARTS	Automated Radar Terminal System
ATC	Air Traffic Control
ATCT	Airport Traffic Control Tower
CAT	Category — of instrument landing system
CCAD	City of Charlotte Aviation Department
CLT	Charlotte/Douglas International Airport
FAA	Federal Aviation Administration
FBO	Fixed Base Operator
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
KTS	Nautical miles per hour
MI	Miles
NM	Nautical Miles
SM	Statute Miles
TRACON	Terminal Radar Approach Control
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions

Notes:

Notes:

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